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ENVIRONMENTAL & INORGANIC RESEARCH SECTION 1984 ANNUAL REPORT

Report No. 85-156-K

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Research Section
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ABSTRACT

In 1984, the section made significant contributions to the state of knowledge and technology in several areas such as; conducting polymers for advanced batteries, separation of hydrogen isotopes by chromatographic methods, ion exchange resin performance in nuclear circuits, decontamination processes, concentration mechanisms and corrosion processes under deposits in nuclear steam generators, steam generator chemical cleaning, and processes for immobilizing high level liquid wastes. New work was started in a variety of areas such as applications of plasma technology and electrochemistry in chemical processes, dew point measurement and molecular sieve drier technology in nuclear applications, and limestone injection for sulphur dioxide removal from stack gases. Ongoing capabilities in combustion research and environmental aspects of solid waste disposal and wastewater treatment were also maintained. Most of these programs will continue in 1985.

job	file	date	report no.
740631-810-081	830.4	May 28, 1985	85-156-K

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To Mr. F. J. Kee
Director of Research

ENVIRONMENTAL & INORGANIC RESEARCH SECTION
1984 YEAR END REVIEW AND 1985 PROGRAMS

1.0 INTRODUCTION

This report contains a summary of the work performed and the results achieved by the Environmental and Inorganic Research Section in 1984 and a description of the direction these work programs will take in 1985.

The section performs research and development on many of the chemical processes that are involved in both the production and utilization of electricity. Generally, these studies are designed to develop or enhance our understanding of the chemical and engineering phenomena of those processes, and/or to develop new or improved processes or procedures which contribute to increased safety, reliability and efficiency. The section also provides advice and guidance on chemical processes and assists others in solving problems relating to specific chemical processes.

The main areas in which the section contributes are shown in Figure 1, which depicts the 1984 expenditure of funds broken down by the Research Division major program areas, and also by the section's focus of effort on specific processes or technologies. Fully 75% of the section's efforts are directed at the nuclear generation program, which includes work on steam generator corrosion and chemical cleaning, purification circuit technology development, gas conditioning technology, nuclear waste, and recently, development, management and participation in an intradivisional program on decontamination of nuclear systems. Other work focuses on research on acid gas emission control processes, and research on direct electrical methods like plasma or electrochemical processes for synthesis of chemicals. About 55% of the work is funded from the division's OM&A budget, the balance being made up by clients supporting specific elements of the work. In addition, a variety of projects are conducted, like fly ash leaching and disposal site monitoring, and coal combustion tests for external clients, which utilize previously established expertise and facilities and are valuable to the Corporation yet do not rely on our OM&A funds. External contracts won by the section in 1984 are listed in Appendix I. Presentations by staff, publications, and reports of work completed in 1984 are listed in Appendices II and III.

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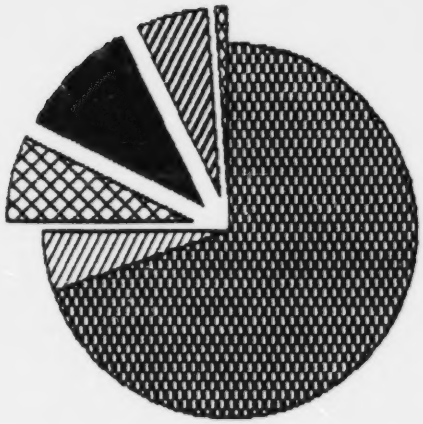
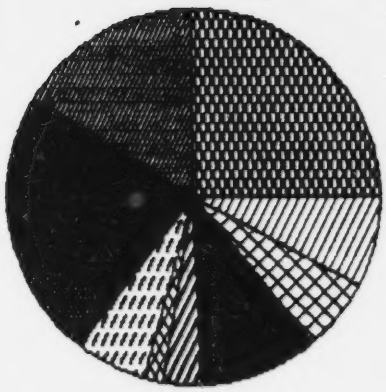
1984 WORK DISTRIBUTION



- NUCLEAR GENERATION	2185.00	(69.7%)
- NUCLEAR WASTE	165.00	(5.3%)
- THERMAL GENERATION	238.00	(7.6%)
- ENVIRONMENT	319.00	(10.2%)
- UTILIZATION	195.00	(6.2%)
- MISCELLANEOUS	35.00	(1.1%)

TOTAL: 3137.00 (100%)

1984 FOCUS OF WORK



- STEAM GENERATOR CORR'N	784.00	(25.0%)
- DECONTAMINATION DEV.	240.00	(7.7%)
- PURIFICATION CIRCUIT TECH	204.00	(6.5%)
- GAS CONDITIONING TECH	326.00	(10.4%)
- RECYCLE ASSISTANCE PGM	106.00	(3.4%)
- ACID GAS EMISSION CONTROL	50.00	(1.6%)
- UTILIZATION	195.00	(6.2%)
- OTHER 'NON FOCUS' STUDIES	735.00	(23.4%)
- CAN-DECON SUPPORT	497.00	(15.8%)

TOTAL: 3137.00 (100%)

FIGURE 1

The forecast work distribution of the section in 1985 is shown in Figure 2. The commitment to the nuclear and nuclear waste programs will be maintained while increased emphasis will be placed on studies on utilization of electricity and the acid gas emission control program. This will be accomplished by reducing the effort spent on capability development work and externally funded combustion testing work in the thermal generation program. The focus of work in those programs is also shown in the figure; the amount of effort on specific focussed programs is forecast to increase from that in 1984, due to reasons already mentioned above and because the amount of support for the on-site CAN-DECON decontaminations will not be as great in 1985.

The section is currently organized with units providing defined functions as shown in Figure 3; the technical support for these units are maintained in a support unit with nominal assignments to specific units where their training and experience is best utilized. The section also utilizes a large number of pilot scale systems in support of its research programs - many of them are essentially permanent installations that meet the need for test systems for particular programs over a long term; these are listed in Table 1, while numerous others are constructed only for particular tests and are then disassembled on completion of the test program.

2.0 UTILIZATION

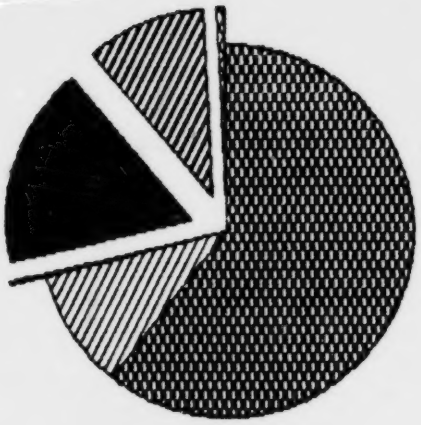
2.1 Electrotechnology Research

A modest electrochemical research program was started in 1983 to assist in developing promising electrotechnologies for application in the Ontario industrial and transportation sector. Successful development of these technologies could result in increased load demand. In addition to monitoring developments in selected technologies, research is underway to develop novel processes and systems and to improve the efficiency and reliability of existing electrochemical processes. A study on research opportunities for development of electrotechnologies was conducted in 1984 which identified a number of areas that should be investigated. They include electroorganic synthesis, battery and fuel cell development and application of plasma technology to chemical processing.

2.11 Electrolytic Hydrogen Generation Technology

In 1984 a literature study was completed on electrolytic hydrogen generation technology. Improvements necessary to increase cost competitiveness of electrolytic hydrogen have been identified and the suitability of these technologies for non-utilization applications such as electrolytic decomposition of tritiated water and hydrogen-isotope separation have been assessed. The study concludes that periodic review of water electrolyser technology be conducted and once advanced electrolysers such as vapour-phase electrolysers become available, they can be tested and their performance assessed.

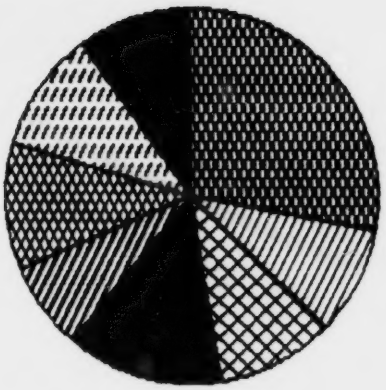
1985 FORECAST WORK DISTRIBUTION



- NUCLEAR GENERATION	2023.00	(60.6%)
- NUCLEAR WASTE	350.00	(10.5%)
- THERMAL GENERATION	8.00	(.2%)
- ENVIRONMENT	580.00	(17.4%)
- UTILIZATION	343.00	(10.3%)
- MISCELLANEOUS	33.00	(1.0%)

TOTAL: 3337.00 (100%)

1985 FOCUS OF WORK



- STEAM GENERATOR CORR'N	937.00	(28.1%)
- DECONTAMINATION DEV.	305.00	(9.1%)
- PURIFICATION CIRCUIT TECH	347.00	(10.4%)
- GAS CONDITIONING TECH	457.00	(13.7%)
- RECYCLE ASSISTANCE PGM	253.00	(7.6%)
- ACID GAS EMISSION CONTROL	375.00	(11.2%)
- UTILIZATION	343.00	(10.3%)
- OTHER 'NON FOCUS' STUDIES	320.00	(9.6%)

TOTAL: 3337.00 (100%)

FIGURE 2

Environmental & Inorganic Research Section

Supervising Engineer - Mr. D.J.R. Dodd (Dave)

Clerk-Stenographer - Mrs. K.D. Wittmann (Kathie)

Corrosion Chemistry Unit	Water Research Unit	Process Chemistry Unit	Process Development Unit
Dr. P. Spekkens (Paul)	Dr. B.R. Nott (Babu)	Dr. M.S. Mozes (Miriam)	Dr. S.H. Hawthorne (Hugh)
Dr. F. Gonzalez (Paco)	Dr. D.R. Chartier (Duane)	Dr. R.K. Kalia (Ramesh)	Dr. C.H. Cheh (Chris)
Ms. A.M. McKay (Sandy)	Mr. J. Complak (John)	Mr. R. Mangal (Rene)	Dr. Y.V. Nguyen (Yen)
Mr. P. McSweeney (Peter)	Dr. A. Golomb (Arnold)	Dr. G.F. Thomas (Gerry)	Dr. V.P. Singh (Vic)
Dr. T.W. Ng (Wing)			
Dr. J.M.T. Raycheba (John)	Mr. W. De Vries (Werner)	Dr. M. Alvarez-Cuenca (Manuel) Special Assignment - Plasma Technolgy	

Supervising Technician - Mr. E.T. Chadwick (Ted)

Mr. L.O. Gibson (Larry)	Mr. A.Z. Mlynarczyk (Alex)	Mr. I.B. Holzheuter (Ingo)	Mr. S.G. Chilakos (Steve)
Mr. P. Leung (Patrick)	Mr. A. Panda (Ashok)	Mr. R.J. Thampi (Raja)	Mr. R.A. Currie (Rick)
Mr. A.C. McBride (Alan)	Mr. W.W. Quan Fun (Wing Way)	(Mr. G. Till (Grenville))	Mr. J. Atherley (Jim)
Mr. E.P. McNeill (Gene)	Mrs. P.M. Williams (Pat)	(on loan to Metallurgical Research)	

Steam Generator Corrosion	Water Treatment Technology	Electrochemistry	Gas Conditioning Technology
Autoclave Studies	Nuclear Purification Circuit Technology	Coal Combustion Technology	H Isotope Separation
Steam Generator Deposit Analysis	Ion Exchange Resins	Chemical Modelling	Molecular Sieve Driers
Electrochemical Corrosion Monitoring	Waste Active Resin Characterization	Air Pollution Control - Process Chemistry	Annulus Gas Studies
Corrosion Product Formation, Transport & Deposition	Fly Ash Leaching & Disposal Site Groundwater Monitoring		Fuel Reprocessing Off-Gas Treatment
Chemical Cleaning Development	Wastewater Characterization & Treatment		Process Chemical Engineering
			Recycle Waste Immobilization
Decontamination Development			Coal Cleaning Technology
			Acid Gas Emission Control

FIGURE 3

TABLE 1

Major Loop Systems

Combustion Research Facility - a 640 MJ/hr (20 kg/h coal) combustion system including coal pulverizer, pneumatic conveyor, down draft combustion chamber equipped with gas and coal burners, air preheaters, air-to-air heat exchangers, ESP and ash resistivity probe, and flue gas and ash sampling systems and associated instrumentation and control systems.

Full Scale Ion Exchange Test Loop - a recirculating test loop with a flow capacity of 10 L/s and capable of operation at temperatures up to 90°C. The facility includes two full scale ion exchange columns (exact replicas of Bruce NGS moderator columns) and is used for chemical and physical testing of ion exchange resin materials and equipment.

Reverse Osmosis Test Loop - a batch recirculatory loop with tubular, spiral wound, and hollow fibre membrane modules. Flux rates for water are up to 0.8 $m^3/m^2 \cdot day$ at 5.5 MPa.

Chemical Cleaning Test Loop - a 60 L stainless steel recirculating loop capable of operation at temperatures up to 140°C and pressures up to 1 MPa with a maximum flow of 1.9 L/s. It has a 20 cm diameter cylindrical sample chamber and is used for chemical cleaning process testing.

Autoclave Laboratory - contains four 3.9 L Inconel 600 and one 1 L Hastelloy C, electrically heated, high temperature (535°C, (340°C Hastelloy)) and pressure autoclaves used for extended duration studies of material corrosion and high temperature electrochemical measurements under simulated nuclear steam generator secondary side conditions. Three are refreshed, once-through systems with feedwater storage and chemical dosing tanks, high pressure piston pump, preheater, 3.9 L autoclave, condenser and pressure control system. The other two are operated as static systems, i.e. with no fluid flow.

Model Boiler - a stainless steel, once-through loop used for evaluating circuit chemistry and materials corrosion. It consists of a water purification and chemical treatment system, three preheaters and an 18L boiler vessel. The system is instrumented and automatically controlled for unattended operation. The electrically heated boiler is designed for temperatures up to 357°C at a feedwater flowrate of up to 300 mL/min.

2.12 Polymer Batteries

A research program aimed at the development of lightweight polymer batteries with high energy and power density and long cycle life suitable for electric vehicle and utility applications is in progress. The first phase of the study, the development and characterization of selected conducting polymers, was completed in 1984. A few conducting polymers such as polythiophene, polypyrrole and HP023 have been prepared, through the electrochemical polymerization of thiophene, pyrrole and substituted thiophenes. A novel polymer HP023 of bridged polyene structure appears to be the most promising as a positive electrode material in a polymer battery. This polymer appears to be stable, and can be p-doped to yield a maximum open circuit potential of 4.2 V versus Li reference electrode. Doping levels of approximately 20% have been achieved on a micro-electrode, and it has shown good charge/discharge behavior. A report is being prepared to summarize the results of the first phase of the study. The study will be continued in 1985. The most promising polymers selected in phase I of the study will be used to fabricate electrodes in 1 cm^2 single cells and later in a multiple cell stack using about 10 cm^2 electrodes. Their performance characteristics such as energy and power density, energy efficiency, charge/discharge behavior, shelf and cycle life will be evaluated.

2.13 Plasma Technology

A state-of-the-art review on the application of plasma to chemical processing is in progress. The study's objectives are to evaluate the technical and economic feasibility of various processes and their application in Ontario, to assess the market potential of the various products which can be produced through plasma processing and to define a research program that will address the development of the most promising process which will be investigated in the Division's plasma research facility.

One of the key elements of chemical processing with plasmas is the ability to quench the reaction at the appropriate point in the reaction. The design and testing of a quenching system for a plasma chemical reactor is nearing completion. A literature survey of existing quenching devices has been completed. Based on the study two novel fluid injection systems of differing geometry and operation were chosen for further studies. Injection quenchers, which are ranked among the most effective quenching devices, are being designed and will be tested in 1985.

3.0 NUCLEAR GENERATION

3.1 Gas Conditioning Technology

3.11 Tritium Handling Technology

A number of projects were undertaken to develop alternative, improved methods to enrich or remove tritium or tritium oxides from gas streams typical of those in fusion reactor systems, nuclear stations and tritium recovery systems. Much of the work was supported by the Canadian Fusion Fuel Technology Program (CFFTP) and section staff also acted as consultants to CFFTP in reviewing reports and designs of equipment pertinent to fusion facilities.

3.111 Hydrogen Isotope Separation in a Moving Bed

In order to develop alternatives to the cryogenic distillation systems currently proposed for detritiating fusion and fission reactor coolant streams, a program was undertaken to develop a countercurrent gas-solids moving bed contactor capable of producing an enriched tritium stream from a mixture of hydrogen isotopes. The overall objective of the program was to develop a design for a prototype adsorption system which could then be tested in an operational environment.

A palladium adsorbent was selected over titanium, vanadium, and molecular sieve because; (1) tritium, being less strongly adsorbed, goes to the top of the column rather than the bottom reducing the possibility of contaminating the solids-lift carrier gas, (2) the operating temperature of the reboiler at the bottom of the column will be lower with palladium as compared to vanadium and titanium, (3) palladium will catalyse T_2 formation from HT and (4) cryogenic operating temperatures will not be required as is the case for molecular sieves. An alumina support was employed to minimize the quantity of palladium (25% on alumina) required while providing a large surface area for reaction.

The bench scale moving bed system (2 cm dia x 145 cm high), designed by Professor D. Basmadjian of the University of Toronto, was built and modified to provide a reliable solids movement system. The alumina granular substrate used to prepare the 25% palladium content adsorbent material displayed significant powdering when recirculated in the solids handling system. A heat treatment procedure was developed to increase the pore size of the substrate while maintaining adequate abrasion resistance.

Performance tests on separating hydrogen/deuterium mixtures were carried out by varying column feed rate, feed composition, product removal rate, solids flow rate, column temperature and carrier gas. At low feed rates of a 1% D_2 in H_2 feed and low solids flow rate, no isotope separation was obtained. Improved performance was obtained with a 30% D_2 feed composition. It was calculated that the palladium requirement per unit area of column was about 34 g Pd per stage for a 1% D_2 feed and 17 g Pd per stage for a 30% D_2 feed. Unfortunately additional work did not result in a significant reduction in the quantity of palladium required. At a palladium cost of $200 Cdn/oz and a 25% processing cost, the total adsorbent cost would be $4,600,000 for a 200 L/day coolant detritiation plant. In addition, a nitrogen carrier gas removal system was estimated to cost about $800,000 resulting in a total cost of $5,500,000. As it has been estimated that for a sorption process to be competitive with cryogenic distillation for coolant processing, the lifetime cost of the adsorbent should be approximately $3,000,000 (1985). Therefore further experimental work on palladium based adsorbents will not be carried out but other alternative materials may be investigated.

3.112 Protium Separation by Gas Chromatography

A project was carried out to demonstrate a hydrogen isotope separation system as part of the fuel purification system of a small experimental fusion facility. The requirements of this system as specified were:

(i) the throughput should be about 1 L/h (S.T.P.) to purify 1000 Ci of tritium from a 55/45 D/T mixture, in one hour.

(ii) the total inventory of tritium in the system must not exceed 5000 Ci and must always be enclosed in an appropriate glove box, in the tritium handling room.
(iii) the system should guarantee a purification from impurities other than protium, better than 1% for low Z(He) and of 0.1% for high Z impurities (C,N,O).
(iv) to avoid the technical difficulties and the risks that can be connected with the use of uranium beds at the high temperatures needed for hydrogen purification, an alternative solution should be provided.

The system selected was low temperature gas chromatography in which the tritium inventory is extremely low and tritiated species are in the less hazardous molecular form. The project was divided into two main phases; bench scale optimization of chromatographic techniques for the separation of protium (H) from deuterium (D) and tritium (T), and design, construction, and testing of a pilot scale system for feed rates up to 1 L/h.

The variables investigated during the bench scale study were column packing material, temperature, column length, and carrier gas. Molecular sieve 5A was found to be equal or superior to all other materials tested and as it is readily available was selected for use with a helium carrier gas.

The order of elution on the molecular sieve 5A column is H_2, HD, HT, D_2, DT, T_2. The resolution of these species is improved by lowering the temperature; above -100°C poor separation was obtained, whereas at -180°C hydrogen is retained indefinitely on the solid substrate. An operating temperature of -150°C to -160°C proved to be optimum with respect to resolution and processing time.

The separation was originally studied on 1/8" OD columns before being studied on 3/8" OD columns. Two 3/8" columns, a 2' and 5' column, were placed in series with the ability to switch the effluent from the shorter column to the exhaust vent at selected times after the initial injection. By varying the sample size and column switching time it is possible to process, with a 3/8" column, 0.5 - 1 L/h while separating all of the H_2 and HD, 85% of the HT and 20% of the D_2 from the main fuel stream which can then be returned to the fusion fuel storage system. The proportion of D_2 which is removed with the protium components can be modified by changing the processing rate.

Detection of hydrogen isotopes is normally accomplished using thermal conductivity (TC) detectors but in this study the concentration of the radioactive species was below the limits of the TC detector. It was necessary to design and build a flow proportional beta-sensitive detector capable of detecting hydrogen isotopes in the nanocurie range. It was found that the response characteristics for this detector were linear and reproducible and the detector can be customized for various applications.

A temperature control system for the pilot scale system has been built and tested and the pilot scale system is being assembled. Columns up to 1" diameter will be employed and optimum conditions established in 1985. Based on the results of the pilot scale work, a system will be designed to permit the construction of a plant to demonstrate the separation of hydrogen isotopes by gas chromatography to potential customers in Europe and North America.

This work is a significant contribution to both the science and the technology of hydrogen isotope separation and will provide a basis for the sale of this technology to potential customers who own small fusion devices.

3.113 Molecular Sieve Driers

Molecular sieve driers are used to remove tritiated water from process streams and atmospheric air at nuclear generating stations, tritium recovery facilities, and fusion facilities. Drier designs have been improved over the years and considerable information is available from molecular sieve manufacturers on material selection and equipment design. However for most nuclear applications, particularly those associated with tritium recovery, commercially available information is not adequate.

A project, funded by CFFTP, was subcontracted to Professor D.M. Ruthven of the University of New Brunswick to study the adsorption of moisture on molecular sieve adsorbents at low humidity. The report on this work was reviewed and revised before final submission to CFFTP. It was concluded that very efficient regeneration of the sieve to low residual moisture contents is necessary to ensure adequate performance to meet the requirement of exit gas dew points of -60°C or less. In addition it was determined, based on equilibrium data, that there is no significant isotopic effect at water vapour concentrations above about 100 uL/L. Therefore molecular sieve dryers for this condition can be designed for the adsorption of DTO/HTO using easily obtainable data for the H_2O/4A sieve system.

A planning document reviewing the application of molecular sieves and detailing further research work has been prepared. In 1985, further studies will be carried out on absorbent materials for D_2O recovery systems and tritium exhaust gas driers and the design of a pilot scale drier will be completed.

3.12 Annulus and Moderator Cover Gas Studies

3.121 Removal of C-14 from Annulus & Moderator Cover Gas

As part of the C-14 Management Program being coordinated by the Nuclear Materials Management Department, the dry $^{14}CO_2$ removal process developed for moderator cover gas was modified for the nitrogen annulus gas system. Bench scale experiments were carried out to test catalysts and develop design data and operation conditions for the pilot scale catalytic oxidizer to convert all carbon species to CO_2. An integrated pilot scale (up to 160 L/min) system including a catalytic oxidizer, a humidifier/demister, a $Ca(OH)_2$ reactor, a condenser/demister, and molecular sieve dryers, was assembled and tested. Pilot plant results showed that CO was oxidized completely and 60 - 100% of CH_4 was oxidized with 0.54% H_2 in the simulated annulus gas. CO_2 was removed to a concentration of 1 uL/L or lower and gas could be dried to less than -40°C dew point before recirculation. Design recommendations for a C-14 removal system for the nitrogen annulus gas were summarized.

A demonstration plant for the removal of C-14 from moderator cover gas will be designed and constructed. The plant will be installed at NPD NGS and operated in late 1985 and the first half of 1986. Upon successful completion of the trials at NPD, the demonstration plant or similar units will be installed at other nuclear generating stations as required.

3.122 Bruce NGS 'B' Annulus Gas System Response

Annulus gas systems in CANDU nuclear generating stations provide thermal insulation between the hot pressure tubes and the relatively cool calandria tubes and surrounding moderator. In addition, leaks from calandria or pressure tubes are indicated by the presence of heavy water (D_2O) in the gas. The annulus gas system at Bruce 'B' is complex, consisting of flow circuits (strings) of four to twelve channels connected in series by tubing, and it uses CO_2. A study was carried out to determine the response characteristics of individual strings with changes in flow rate, leak rate, and number of channels in the string.

3.2 Nuclear Purification Circuit Technology

The ability to maintain appropriate purity and chemical composition in the moderator, primary heat transport system (PHTS) and irradiated fuel bay (IFB) of our nuclear stations is necessary for the safe operation of these stations. The purification circuits on these systems employ ion exchange (IX) resins which have, in the past, not always performed as well as expected. In addition, the spent resins are radioactive and are costly to dispose in active waste disposal. The study of these problems and their solutions lead to the development of a research program aimed at providing more efficient, reliable and less expensive (in terms of replacement sorbent cost and storage costs for spent, radioactive sorbents) technology for purifying the circulating water in the PHTS, moderator and IFB under existing and potential future operating conditions. Much of the work is cofunded by the Technical and Training Services Division and Design and Development Division - Generation. The current status of projects in this program, and the planned work for 1985 are described below.

3.21 IX Resin Quality Assurance Program

The test program to find a suitable ion exchange resin to replace the discontinued Amberlite IRN-300 (Rohm and Haas) resin mixture, which has been used for gadolinium nitrate removal from moderator purification circuits, was continued in 1984. Mixtures of strong acid cation and weak base anion resins from several resin manufacturers were evaluated in detail. It was found that there were problems associated with kinetic performance of the weak base anion component of resins from all of the manufacturers. Extreme interbatch variability in performance was also noted for all the mixed bed resins tested. One resin was recommended as the provisional substitute and another was found to be a suitable substitute if slurryability of the resin mixture could be improved.

In the course of this work it was evident that fundamental work aimed at resolving problems of kinetic performance of weak base anion resins should be carried out and this will be undertaken in 1985.

Additionally, test procedures were developed and formalized to facilitate setting performance specifications for the resins. In 1985, these procedures will be used to evaluate additional resins from various manufacturers for service in the various purification circuits (PHTS, moderator and IFB) in order to increase the flexibility of resin supply and ensure that stations will always be able to obtain supplies of resins that are known to perform satisfactorily.

3.22 IX Resin System Improvements

3.221 Resin Utilization in IX Columns

Tests were performed in the Research Division's full scale Ion Exchange Test Facility to determine the degree of utilization of ion exchange resin in a full scale moderator ion exchange column. A strong acid cation resin was exhausted with a sodium hydroxide solution and resin samples from several locations of the resin bed were analyzed. It was determined that sodium loadings on the resin were considerably lower near the edges (walls) of the cylindrical vessel than at the center, especially in the middle and bottom layers of the resin bed, leading to poor resin utilization. This was attributed to high column flows and some of the peculiarities of the column itself, a cylindrical, conical bottom vessel with a small outlet distributor located at the center of the conical bottom.

Further tests were carried out to determine the effect of flow rate on resin utilization. Tests on a weak base anion resin revealed very poor resin utilization at a flow of 70 bed volumes per hour (BV/h) and a five-fold improvement when the flow was reduced to 20 BV/h. These tests will continue in 1985 using strong base anion exchange resins and mixed bed resins.

3.222 Optimum Cation/Anion Ratios in Moderator Mixed Beds

It is believed that a significant portion of the cation resin component in the 1:1 equivalent mixed bed resin is not used during normal moderator purification. In 1985 a program will be undertaken to evaluate the performance of mixed bed resins - comprising varying cation/anion ratios, for normal moderator purification (ie, B removal). The objective is to determine the ratio for optimum performance (ie, minimum replacement resin usage and spent radioactive resin waste volume).

3.23 Alternate Sorbents

Very little work was done this year on evaluating alternate sorbents to conventional organic ion exchange resins for the various nuclear purification circuits, due to pressure from high priority work (eg, CAN-DECON). However, it is planned to resume work on this in 1985 with a comprehensive program to systematically evaluate sorbents with high selectivities for specific nuclides for use in the PHT, moderator and IFB purification circuits with the objective of minimizing the volume of sorbent usage and of radioactive sorbent waste volume. The sorbents to be tested will include inorganic ion exchangers, chelating resins, crown ethers, and special proprietary materials such as the DeVoe-Holbein compounds.

3.24 IX Resin Database

The chemical and operating data on ion exchange resin performance during CAN-DECON were analysed by computer in order to compare results from laboratory simulations with field data. In 1985 this will be extended with the development of a database containing all the relevant information on the performance of ion exchange resins in the various purification circuits in CANDU reactor systems. The database will facilitate assessment of the large volumes of related data en masse for ion exchange problem-solving and relating performance characteristics amongst systems with different physical dimensions.

3.25 Characterization of Spent Resins

Spent ion exchange resins from the various purification circuits in Hydro's nuclear generating stations constitute a significant medium activity waste with a large disposal cost. The chemical and radiochemical composition of the spent resins have to be ascertained in order to develop processes for their treatment and disposal. Such information is also necessary to help understand the chemical conditions the resins are operating in and their performance under actual station conditions.

Although a few studies to analyse and treat active resins have been performed in previous years, the level of activity on these resins has precluded extensive work on larger samples. Therefore to minimize radiation exposure to operating personnel during 'handling' and processing of the active resins the design and construction of a laboratory test facility for 'remote' handling of spent radioactive (>2 R/h contact field) ion exchange resins was undertaken. The facility is intended to be used for performing chemical and radiochemical analyses of spent resins as well for development of treatment processes for spent resin waste volume reduction. Assembly of the major components of the facility has been completed. It is expected that the facility will be completed and established in the Radioactive Materials Laboratory early in 1985.

On completion of the remote resin handling facility, a program will be undertaken to systematically analyze samples of spent resins from the PHT and moderator systems of Hydro's nuclear stations. Analyses will include gamma spectroscopy, alpha spectroscopy (for PHT resins) and measurement of C-14 and tritium, etc. Arrangements for sample collection are being made by the Training and Technical Services Division - Radioactive Materials and Environmental Protection Department, and Design and Development Division - Nuclear Materials Management Department with assistance from Research Division staff. Plans are being made to analyze at least four resin samples in 1985.

3.3 Decontamination Development Program

The urgent need to decontaminate the primary heat transport systems of Pickering Units 1 and 2 resulted in a major effort on technical support for the on-site decontaminations and on decontamination process development. Section personnel participated in the decontamination program. Project management and coordination was provided by section staff for the decontamination work at Research Division. The work was cofunded by the Technical and Training Services Division and Design and Development Division - Generation.

3.31 Corrosion Inhibitors

Screening tests were carried out of the effect of ion exchange resins on corrosion inhibitors in the solvent. A study of chemical corrosion inhibitors and their role in the CAN-DECON process was initiated. A literature survey on inhibitors will be completed by early 1985 and a experimental program will be undertaken to evaluate different types of inhibitors.

3.32 CAN-DECON Solution Chemistry

A computer model which includes the important chemical equilibria occurring in a CAN-DECON solution was developed in order to establish conditions under which ferrous oxalate precipitation will be avoided. Detailed data interpretation of a 32-run matrix of simulations has been completed and a report is being prepared. It was found that in the majority of simulations no ferrous oxalate precipitation is predicted, and in the simulations where precipitation is predicted, it occurs only above a certain pH, generally between 3.5 and 4.5. In 1985, the model will be altered to calculate the pH of a solution containing specified analytic concentrations of reagents and metal ions. In addition, the model will be expanded to include Ni(II), Cu(II), Co(II), and Cr(III) ions.

A computer-based system was developed for storing and manipulating the chemical data which is collected during a CAN-DECON decontamination and was used for process control.

3.33 IX Resins in Decontamination Systems

A number of projects related to ion exchange during decontamination were performed in order to solve problems arising from retention of EDTA on cation resins, and the potential problems that would arise if resins were exposed to alkaline permanganate solutions. A longer term program to develop more efficient and inexpensive technology for removing radioactivity from CAN-DECON solutions and to reduce volumes of radioactive ion exchange wastes was undertaken.

3.331 EDTA-IX Resin Interactions

A series of laboratory simulations were performed to attempt to reproduce the EDTA retention phenomenon observed on cation exchange columns during reactor decontamination and to conduct parametric studies on the factors which may influence the extent of EDTA retention. While the first tests using small resin beds (38 mL) indicated some EDTA retention, the columns appeared to release EDTA much faster than was observed in the field. Although EDTA retention was more prolonged in later tests with full-depth resin beds, there still appeared to be differences between the results of laboratory simulations and field conditions.

In order to facilitate comparisons of laboratory simulations and field behavior, the data collected in the field and from the simulations are being analyzed in terms of dimensionless parameters. This will continue in 1985 and may lead to further laboratory simulations later in the year.

In addition in 1985, techniques to remove EDTA retained by the cation exchange columns during CAN-DECON will be explored, possibly in the full scale test facility, to improve the efficiency and to minimize problems related to ion exchange handling following the decontamination.

3.332 CAN-DECON IX Resin Analyses

Samples of spent ion exchange resin (cation) and slurry water from the Pickering Unit 1, March 1983 decontamination were analyzed. EDTA was found mainly in the slurry water, with relatively little on the cation resin. The quantities detected were, however, considerably less than the amounts believed to have been retained during the decontamination. The results indicated that

binding of the EDTA to the resin was very weak and that most of the EDTA was displaced from the column during dedeuteration. Similar results were seen with spent resins from the Nuclear Power Demonstration NGS December 1983 and Pickering Unit 1, 1984, decontaminations. Analyses of additional spent CAN-DECON resin samples will be performed if and when they become available. This will facilitate better understanding of the various resin-reagent interactions.

3.333 Alkaline Permanganate/IX Resin Interactions

Laboratory tests were performed on small ion exchange columns to determine the effect of exposing cation and mixed bed resins to alkaline permanganate solutions. It was determined that the mixed bed resin, Amberlite IRN-150 was quite effective in sorbing $KMnO_4$ from a 0.1% solution at high pH (approx 11). It appeared that only the anion resin is affected by $KMnO_4$ uptake. It was concluded that there should be no significant operational problems with ion exchange resins with alkaline permanganate. However, there are some concerns from the point of view of storage and disposal of the spent resins, because of the potential for oxidation of the resin by residual oxidizing species which may be present on the anion sites. These concerns will be addressed in tests carried out in 1985.

3.334 Alternate IX Systems

Work will be carried out in 1985 to investigate the feasibility of alternate techniques for ion exchange regeneration of the reagent for application to future CAN-DECON decontamination systems.

Sorbents having high selectivities for Co^{2+} (over Fe^{2+}) may be capable of selectively removing cobalt from CAN-DECON solutions. A program to test several alternate sorbents such as inorganic exchangers, chelating resins and special proprietary formulations such as DeVoe-Holbein compounds, will be undertaken in 1985.

The Co-60 sorbed on the cation resin during a decontamination travels down the column in a band. Isolation of a small volume of resin containing the Co-60, for example by adding a small additional column downstream of the main cation column, may be beneficial in reducing radioactive waste volumes. To examine the feasibility of this approach, the characteristics of the cobalt front will be determined in laboratory tests which will be conducted in 1985.

3.4 Steam Generator Corrosion

3.41 Autoclave Studies

The major threat to steam generator integrity is corrosion under the sludge piles which have accumulated on the tubesheets. On-going programs continued in 1984 in laboratory autoclaves and in blowdown-line autoclaves at Bruce NGS 'A' and 'B' to study the nature of the environments formed under the sludge piles and the type and extent of corrosion observed.

Laboratory autoclave experiments have been carried out using probes which simulate the sludge-filled tube/tubesheet intersection region. Experiments to study the rate of the concentration of soluble impurities under the sludge have shown that the "concentrating depth" of a sludge pile, ie, the depth to which concentration of impurities is actively taking place, is a strong function of the porosity of the sludge, with lower porosity sludges exhibiting

shallower concentrating depths than higher porosity sludges. The distribution of chloride in the sludge pile was determined. High concentrations were detected at depths greater than the "concentrating depth", probably due to occasional wetting of the full depth of the pile. Experiments were performed in refreshed autoclaves to determine the nature and extent of attack on steam generator materials. It has been shown that the presence of lake water and dissolved oxygen in the feedwater promotes the formation of fast linear grown magnetite on carbon steel and pitting on Inconel 600 tubes under the sludge pile, even at relatively low concentrations of contaminants. The laboratory autoclave test program for 1985 will examine the role of individual contaminant species including $SO_4^=$ and $SiO_2^=$ on corrosion of steam generator materials under sludge piles. Some of these experiments will be done under accelerated conditions using potentiostatic methods. Tests will also be carried out to determine the effect of condenser in-leakage on the corrosion of Darlington steam generator materials, and of chemically-cleaned Bruce steam generator materials and water-jetted Pickering steam generator tubes.

The construction and installation of the test probes for the blowdown line autoclaves at Bruce NGS 'A' and 'B' was completed. A water level sensing device was designed, constructed and installed to protect the probe heaters in case of loss of blowdown flow. The probes will be used to monitor long-term (5-year) scaling and corrosion behavior of steam generator materials in actual steam generator water. Some specially constructed probes have been installed at Bruce NGS 'B' to determine the effect of stress on corrosion. Probes are to be removed periodically for destructive examination. The first probe removal is scheduled for 1985.

3.42 Steam Generator Deposit Analyses

Samples collected from the tubesheet sludge pile of Pickering Unit 2 Boiler 10 were examined. Water which seeped from the sludge pile during the sampling was found to contain high concentrations of ionic contaminants such as Na^+Cl^-, $SO_4^=$ and Ca^{++}, indicative of "hide-out" under the sludge of these impurities present at low levels in the feedwater. The solid samples were examined by a variety of analytic techniques and found to consist mainly of Fe oxides (principally Fe_3O_4), metallic Cu and calcium species ($CaCO_3$, $CaSO_4$). Sulphur concentrations were in the range 0.3 - 2% and Electron Spectroscopy for Chemical Analysis showed the sulphur to be present as $SO_4^=$ and $S^=$. The recently obtained tubesheet sludge samples from Bruce Unit 3 Boiler 3 and Pickering Unit 1 Boiler 3 will be examined in 1985, with particular emphasis on the nature of the sulphur species present.

3.43 Electrochemical Corrosion Monitoring System

Development of an electrochemical system for investigating corrosion phenomena at steam generator temperatures and pressures continued. A facility was assembled and software developed to carry out DC electrochemical measurements under computer control. The system was successfully tested at ambient temperatures. A high temperature electrode was designed and constructed and an autoclave suitable for electrochemical measurements was assembled.

Work in 1985 will consist of the testing of the DC electrochemical corrosion monitoring system at steam generator temperatures and pressures and the acquisition of an AC impedance system for electrochemically investigating corrosion, particularly in inhibited systems.

3.44 Corrosion Product Formation, Transport and Deposition

Work was carried out on several aspects of the formation, transport and deposition of corrosion products in the secondary circuit of CANDU reactors. The assembly of the Model Boiler Test Loop continued with the installation of a gamma densitometer level alarm system. The loop assembly and commissioning are to be completed in 1985, and an experimental program to test alternative pH-control and oxygen-scavenger feedwater treatment chemicals is to be undertaken.

A report was issued reviewing the literature on methods of sampling particulates from high temperature and pressure aqueous systems. An experimental program was carried out to evaluate the Prototron ILI-1000 laser particle counter as an on-line corrosion product monitor. The instrument was found to be unsuitable and alternative systems were recommended for testing. A project was undertaken to study the agglomeration behavior of magnetite particles in aqueous suspension. This work will be continued in 1985, particularly investigations of chemical methods of preventing particle agglomeration. Also, the construction of a test loop to study the factors that affect particle deposition will be completed in 1985 and an experimental test program will be initiated.

3.45 Chemical Cleaning Development

3.451 Steam Generator Cleaning

Work continued on the development and testing of a chemical cleaning process for the tubesheet region of a Bruce NGS steam generator. This work was largely funded by the Technical and Training Services Division.

The optimum chemical composition of the iron- and copper-removal solvents was recommended. The iron removal solvent consists of an ammoniated 10% ethylenediaminetetraacetic acid (EDTA) solution at 90 - 95°C, containing 0.5% hydrazine, 0.7% corrosion inhibitor and an anti-foaming agent. The copper removal solvent contains 5% EDTA, 2% H_2O_2, ethylenediamine for pH adjustment to 9.0 - 9.5, and an anti-foaming agent. An extensive series of tests was carried out to determine the factors which accelerate the decomposition of peroxide in the copper solvent. Increasing temperature and the presence of NH or residual iron-removal solvent were found to have a major effect in increasing the rate of decomposition of the peroxide.

Flow visualization experiments were carried out using a full scale mock-up of the Bruce NGS steam generator tubesheet area. It was found that the maximum flow through the bundle is obtained when the solvent enters through the diametral box header and exits through the four opposite peripheral blowdown lines. Under these conditions, a total flow of 5 L/s through the steam generator produces a solvent velocity of 2.5 cm/s at a water depth of 20 cm. It was found that the sludge pile in the bundle does not represent a barrier to the flow, provided that the water level is higher than the sludge pile.

Dissolution tests in the Chemical Cleaning Test Loop have shown that entrainment of sludge particles is an important factor in sludge dissolution when the velocity of the solvent was >1.5 cm/s. At lower velocities, dissolution of the sludge was poor. These tests were, however, carried out with soft sludge which may behave quite differently from the rock-hard steam generator sludge pile. Attempts to produce artificial hard sludge for use as

a test material have been unsuccessful. These experiments will be continued in 1985.

Corrosion testing of steam generator materials in the chemical cleaning solvents showed acceptably low general corrosion rates for all the alloys. Autoclave and isothermal capsule experiments were carried out to determine the effect of residual chemicals and sludge which may be left in the steam generator after an unsuccessful clean. In the autoclave tests, carbon steel specimens imbedded in solvent-impregnated sludge and exposed to steam generator temperatures showed weight losses up to 20 mg/cm^2. Chemical analysis of the decomposing residual solvents failed to detect the formation of any polythionates or thiosulphate from decomposition of the inhibitor. Bench scale experiments showed that most of the sulphur present in the inhibitor is converted to sulphate when exposed to a solution containing H_2O_2. Further corrosion testing is to be carried out in 1985, particularly of localized corrosion phenomena during and after a chemical clean. A physical aid to steam generator cleaning, a pressure pulsing system developed by ANCO Engineers Inc, will also be evaluated in the Flow Visualization Loop.

3.452 Boiler Cleaning Solutions Waste Treatment

Spent solutions resulting from cleaning operations of boilers in nuclear generating stations, are expected to contain high dissolved solids (eg, weak organic acids and methods will have to be developed to treat the waste solutions probably by oxidizing the organic acids and precipitating the metals to enable their safe disposal.

3.453 Shutdown Cooling Heat Exchangers

The deposits on the OD section of Monel-400 shutdown cooling heat exchanger tubing from Pickering Unit 7 were examined and tests were conducted to identify a suitable chemical cleaning solvent. The tube deposits were found to consist mainly of $CaCO_3$, with small amounts of silica and iron oxides. An inhibited solution of citric acid and formic acid was found to rapidly dissolve the deposits while producing an acceptably low level of corrosion for carbon steel and Monel 400.

3.5 Miscellaneous Nuclear Studies

3.51 Deuterated Lubricants

A proposal was prepared to undertake the theoretical investigation of deuterated lubricants at the request of the Training and Technical Services Division - Central Nuclear Services Department. This study will be carried out in 1985 and seeks to provide a minimal understanding of the nature of the observed improvement in the oxidative stability of d-lubricants. The program will involve a review of the literature on the deuterium isotope effect in organic systems, acquisition and implementation of a kinetic isotope effect code, and the formulation of a request for proposal to Ontario university personnel to provide expertise in modeling the force fields present in reacting lubricants, antioxidants, and in transition state complexes.

4.0 NUCLEAR WASTE

4.1 Reactor Operating Wastes (Refer to Section 3.25)

4.2 High Level Wastes

4.21 AECL Recycle Assistance Program

As part of the Recycle Assistance Program to AECL a work program was undertaken on the management of high level waste from the Amine process for dissolution and separation of irradiated fuel. In addition, preliminary investigations into the recovery of valuable byproducts from CANDU fuel were started. The program will be expanded in 1985 to include the conceptual design of an off-gas treatment system and the evaluation of the technical and economic feasibility of byproduct separation. The Amine waste immobilization project is described in greater detail below.

4.211 Amine Waste Immobilization

Existing processes for waste immobilization were reviewed to determine which was best suited for immobilization of the waste (uranium and fission product) stream from the Amine process. The processes that were reviewed were vitrification, Synroc, Eldorado fuel fabrication, and sol-gel.

On the basis of lower final waste volumes and dust-free operation the sol-gel process was selected as most suitable for incorporating fission products into a UO_2 matrix. The composition of the high level liquid waste from the Amine process was determined in discussions with AECL and a simulated waste prepared. Bench scale experiments were carried out to determine the technical feasibility of immobilizing fission products into a uranium dioxide matrix using the sol-gel process.

Initial experiments utilized uranyl nitrate only without fission products, to acquire experience in developing the process. Different techniques were studied and refined until it was possible to produce 1-2 mm uranium dioxide spheres which retained their integrity during subsequent processing. In subsequent experiments with simulated fission products present, satisfactory uranium dioxide spheres were produced and tests made to determine if the fission products were retained within the gelled spheres.

A preliminary process flow sheet was developed for a 6 kg/day uranium pilot plant to permit preliminary economic assessment of the process. This flow sheet will be modified as additional information is obtained. In 1985, it is planned to design, build and commission the pilot plant. Also, methods for removing or tying up fission products like cesium and strontium will be developed.

4.22 AECL Technical Assistance Program

As part of the Technical Assistance Program to AECL for high level waste disposal technology development, an algorithm was developed for modeling the instantaneous inventory of radionuclides within the compartments, and the external output flow from each compartment of a multi-compartment system, given the initial inventory of radionuclides and the input flow into each compartment. An efficient scheme to generate a set of quadrature points and weights for use in evaluating the convolution integral over the input flows

was also investigated. The algorithm is also applicable to the numerical solution of the reaction-diffusion equation of a multi-component system in an infinite medium. The algorithm is currently being coded for applications within the context of a nuclear fuel waste disposal concept. A report will be issued within the first half of 1985.

5.0 THERMAL GENERATION

5.1 Combustion Research

There is a continued demand of Ontario Hydro's Combustion Research Facility (CRF) for evaluating fuels from external sources. To be able to meet those demands, we are continuing to upgrade our facility with the addition of an isokinetic sampling system, a coal pulverizer and a pneumatic conveying system, and computer-based data acquisition and control systems.

A large program was conducted to evaluate the combustion characteristics of a few western Canadian coals and their beneficiated products for a western Canadian coal company. There have been expressions of interest from other agencies in Alberta who would like to conduct combustion testing of their oil agglomerated coals in 1985.

6.0 ENVIRONMENTAL

6.1 Acid Gas Emission Control

Section staff undertook to coordinate the department's participation in new Corporate initiatives in acid gas emission control strategy development. Initially, advice was provided on the feasibility and economics of coal cleaning for the Design and Development Division - Generation study. Subsequently, a coordinating role was undertaken in a research program prepared in response to a request from Design and Development Division - Generation, to develop the limestone injection process in bench and pilot scales including waste disposal so that the technology can be considered as a long term viable option for Ontario Hydro to control SO_2 emissions from fossil-fueled stations.

6.11 Furnace Limestone Injection - Pilot Scale Combustion Tests

The pilot scale study is to be conducted at the Combustion Research Facility (CRF) and its objectives are to optimize the parameters affecting SO_2 capture, calcium utilization, and ESP performance, and to minimize slagging and fouling on furnace heat transfer surfaces, and to provide input into the upcoming Lakeview TGS demonstration test program. Initially, tests will be performed using the coal and limestone to be used at Lakeview TGS, and under conditions simulating the operating conditions at both Lambton and Lakeview stations.

6.12 Furnace Limestone Injection - Waste Disposal

The fly ash waste resulting from the furnace limestone injection process is expected to contain a high proportion (up to 40%) of highly reactive quicklime and can cause potential handling and disposal problems. A program will be carried out to determine the nature of the waste, the extent of its reactivity (heat of hydration) and to come up with treatment schemes to enable safe handling and disposal of the waste in an environmentally suitable manner.

6.2 Water Pollution Control

There is continuing effort in the area of characterization and treatment of wastewaters from thermal generating stations. Most of this work is funded by the Technical and Training services Division, Supply Division, and Design and Development Division - Generation. One focus of this program has been the characterization of the leachate arising from disposal of coal fly ash through laboratory leaching studies and monitoring actual disposal sites. At present, groundwater monitoring programs are maintained at ash disposal sites at the Domtar Quarry, the Booth Quarry and at Atikokan and Thunder Bay TGS. To date, no adverse effects on the quality of ground or surface waters in the vicinity of the ash sites have been observed due to ash placement. In 1985, the monitoring activities at the ash disposal sites at Domtar Quarry, Booth Quarry and at Atikokan TGS will continue at about the same level as last year. The level of effort at Thunder Bay TGS will be somewhat lower.

6.21 MOE Leaching Test

Work continued on the test program to evaluate the suitability of the MOE's proposed Leachate Extraction Procedure (1984 Revision) for determining the hazardousness of leachable solid wastes such as fly ash and to compare results from it to those obtained with our previous methods. A number of improvements were suggested to the procedure and preliminary comparison of results with results from our previous method indicated that there were not sufficient differences to alter the conclusions that would be drawn from the two test methods. The project then concentrated on determining the suitability of coal ash stockpiled at Lambton TGS (fly ash and bottom ash), Nanticoke TGS (fly ash), and Lakeview TGS (bottom ash) for use as backfill. In 1984, representative (multi-strata) samples from each stockpile were subjected to the MOE Leachate Extraction Procedure (1984 Revision). Samples have also been prepared of concrete containing lignite fly ash from Thunder Bay TGS. In parallel with the MOE (tumbler test) procedure, the same samples have been subjected also to the multiple-extraction (shake test) procedure adopted over the last several years by Ontario Hydro. Testing will be completed, the results interpreted, and a detailed report written during 1985.

6.22 PAH Survey

The investigation to identify and quantify polynuclear aromatic hydrocarbons (PAHs) in waste waters associated with Ontario Hydro's coal-fired generating operations continued in 1984. Preliminary studies have been carried out on representative samples of coal pile drainage, ash sluice waters and fly ash leachate from selected sites. It was found that all of the aqueous samples contained complex mixtures of background organics (non-PAH). Aqueous concentrations of PAHs were low, ranging from 0.05 to 10 ug/L. Phenanthrene and certain of its derivatives were the most widely found PAHs. None of the PAHs identified have been reported to have carcinogenic activity.

6.23 Seeded 'RO' Test

A study to investigate the feasibility of applying 'seeded' reverse osmosis to treat calcium sulfate bearing wastewaters, such as fly ash leachate, was completed in 1984. It was determined that seeded RO would be a less expensive alternative to evaporation for fly ash leachate treatment.

7.0 ACKNOWLEDGEMENTS

The staff of the Environmental and Inorganic Research Section have worked hard to maintain essential forward looking research activities while striving to accommodate additional programs and solve problems of a more immediate nature. It was their dedication and excellent work, and the helpful advice and support of our clients that provided the results described in this report. Their assistance in the preparation of this report is also greatly appreciated.

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APPENDIX I

1984 EXTERNAL CONTRACTS

E&IR SECTION EXTERNAL CONTRACTS (1984)

Funding Agency	Description	Contract Value K$	Project Manager	Duration	Date of Award	Comments
Esso Resources Canada Ltd	Testing of beneficiated coal	120	Dr. M. Mozes	10 months	840118	Complete
Concord Scientific	NOx control tests	6	Dr. M. Mozes	6 months	8307	Complete
AECL Engineering Co	IRN-300 resin tests	7	Dr. B. Nott	5 months	840831	Complete
CFFTP	Moving bed process for H-isotope separation	85	H. Hawthorne	15 months	840104	
CFFTP	Fusion fuel clean-up by GC	65	H. Hawthorne	12 months	840115	
CFFTP	Frascatti design review	8	H. Hawthorne	10 months	840410	
CFFTP	Revisions to molecular sieve reports	5	Dr. V. Singh	4 months	840126	Complete

APPENDIX II

EXTERNAL PUBLICATIONS & PRESENTATIONS

EXTERNAL PUBLICATIONS, E&IR STAFF, 1984

Author	Title, Journal, Publication Information
Dr. G.F. Thomas and G. Till	The Dissolution of Unirradiated UO_2 Fuel Pellets Under Simulated Disposal Conditions Nuclear and Chemical Waste Management, Vol 5, pp 141-147, 1984.
Dr. G.F. Thomas	Enhanced Tritium Production for Fusion Reactors Via 3He (n,p) 3H in the Heavy Water Moderator of a CANDU Reactor Journal of Fusion Energy.
Dr. G.F. Thomas and G. Till	The Dissolution of Unirradiated UO_2 Fuel Pellets Journal of Nuclear and Chemical Waste Management.

EXTERNAL PRESENTATIONS, E&IR STAFF, 1984

Author	Title, Conference, Date/Place
Dr. C.H. Cheh	Removal of 14C from Nitrogen Annulus Gas Department of Energy Nuclear Airborne Waste Management and Air Cleaning Conference Baltimore, Maryland, August 13-16, 1984
Dr. A. Golomb	Reverse Osmosis Treatment of Coal-Fired Power Plant Wastewater Seventh Montreal Symposium on Wastewater Treatment IAWPRC Research Session Montreal, Quebec, November 20-21, 1984
Dr. F. Gonzalez and P. Spekkens	Localized Concentration Processes and Corrosion in Nuclear Steam Generators 9th International Congress on Metallic Corrosion Conference Toronto, Ontario, June 3-7, 1984
Dr. R. Kalia	Rechargeable Batteries Using Polymers as Active Electrode Materials Winter meeting of Ontario/Quebec Section of the Electrochemical Society University of Toronto, Toronto, Ontario, February 17, 1984

APPENDIX III

CATEGORY A & B REPORTS

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GENERAL

Report No	Title	Author(s)	Issued	File
C84-76-K	Sulphate Concentrations in Powerhouse Relief Well Waters R.H. Saunders GS	J. Complak	Sept/84	833.303
C84-124-K	Trip Report: 30th Annual Conference on Magnetism and Magnetic Materials, San Diego, CA, November 26-30/84	D. Chartier	Dec/84	830.5

UTILIZATION

Report No	Title	Author(s)	Issued	File
C84-52-K	The 165th Spring Meeting of the Electrochemical Society, Cinncinnati, Ohio, May, 1984	J. Raycheba	June/84	836.333
C84-74-K	Attendance at Sixth DOE Battery and Electrochemical Contractors Conference	R. Kalia	Aug/84	836.74
C84-104-K	Attendance at the 166th Meeting of the Electrochemical Society	R. Kalia	Nov/84	836.74
C84-109-K	The 19th Energy Conversion Engineering Conference (IECEC) San Francisco, CA August 19-24, 1984	M.S. Mozes	Jan/85	836.7

NUCLEAR GENERATION

Report No	Title	Author(s)	Issued	File
84-13-K	Ontario Hydro Nuclear Steam Generators: Design, Thermal and Hydraulics Corrosion Program	F. Gonzalez	July/84	836.3332
84-63-K	Extraction of Copper from Steam Generator Deposits Using Hydrogen Peroxide as an Oxidizing Agent	P. McSweeney	June/84	836.333
84-136-K	Resin Utilization in Ion Exchange Columns	B. Nott	Apr/84	836.3332
84-163-H	Analysis of a Spent Ion Exchange Resin and Slurry Water Sample from the Pickering NGS - Unit 1 Decontamination: March, 1983	D. Chartier	Aug/84	836.29
84-233-H	Qualification of Ion Exchange Resins for Gadolinium Removal from Moderator Purification Circuits	D. Chartier	Oct/84	836.3332
84-236-K	Removal of Carbon 14 from Nitrogen Annulus Gas	C. Cheh	Sept/84	837.245
84-241-H	AECL IRN-301 Resin Tests	D. Chartier	Aug/84	836.3332
84-265-H	Particle Analyzer for High Pressure and Temperature System - Preliminary Tests	T. Wing Ng	Nov/84	836.333
84-350-H	Decontamination Filer: A Data Handling Computer Program	J. Raycheba	Nov/84	836.29

Report No	Title	Author(s)	Issued	File
84-411-H	The Effects of Alkaline Permanganate on Mixed Bed Ion Exchange Resin	D. Chartier	Mar/85	836.29
C84-13-K	Analysis of a Resin Sample from Douglas Point NGS	D. Chartier	Jan/84	836.3332DOU
C84-15-K	Carbon Steel Corrosion Inhibitor Performance on Elution from Cation Exchange Resin Columns	J. Raycheba	Feb/84	836.29
C84-16-K	Effect of Inhibitors on CAN-DECON Ion Exchange Resins	B. Nott	Feb/84	836.29
C84-18-K	Simulations in Support of NPD and Pickering Unit 2 Decontamination	D. Chartier	Feb/84	836.29
C84-29-K	Basic Language Subroutines for the HP85 Computer	J. Raycheba	Mar/84	836.333
C84-35-H	CANDECON Support Work Dec '83 - Jan '84	P. Spekkens	Apr/84	836.29
C84-45-H	Testing of Ionac M-757, Lot 3	D. Chartier	Apr/84	836.3332
C84-47-K	1984 Nuclear Chemistry Technology Update Conference Trip Report	T. Wing Ng	May/84	836.333
C84-50-K	Pickering Annulus Gas Rotameter Calibration	R. Currie	June/84	836.46
C84-57-K	Boiler Tube Deposits - Lakeview Units 7 and 8	P. McSweeney	June/84	836.333
C84-67-H	Testing of Ionac M-757 (Lots 4 and 5)	D. Chartier	July/84	863.3332

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C84-68-K	PO_4 Removal from Pipe Cleaning Waste Pickering NGS 'B' - Raw Data	J. Complak	Aug/84	837.39
C84-72-K	Visit to the Tritium System Test Assembly, Los Alamos, New Mexico, May 29-30/84	V. Singh, C. Cheh, H. Hawthorne	Sept/84	836.461
C84-78-H	Ionac M-757 Variable Kinetic Performance	D. Chartier	Aug/84	836.3332
C84-82-K	Sludge and IX Resins Bruce NGS 'A'	J. Complak	Aug/84	836.3332BRU
C84-85-K	Leak Site Identification in the Containment Envelope of Nuclear Power Plants - Preliminary Study Using SF_6 Tracer Gas	R. Currie, H. Hawthorne	Sept/84	835.6212
C84-97-K	Examination of Shutdown Cooler Deposit - Pickering NGS 'B', Unit 7	P. McSweeney	Dec/84	836.3332
C84-98-K	American Nuclear Society International Meeting on Fuel Reprocessing and Waste Management	Y. Nguyen	Oct/84	837.82
C84-101-CON	Bruce 'B' Annulus Gas Study	C. Cheh, V. Singh	Nov/84	836.46
C84-127-H	Annulus Gas Dew Point Measurement	S. Chilakos, V. Singh	Jan/84	836.46

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NUCLEAR WASTE

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C84-62-K	Visit to Battelle Pacific North Lab, Richland, Washington, May 31 - June 1, 1984	C. Cheh, H. Hawthorne	July/84	837.82

THERMAL GENERATION

Report No	Title	Author(s)	Issued	File
84-226-K	The Combuation Research Facility Phase II Commissioning with Pulverized Coal	M. Alvarez-Cuenca, R. Mangal, R. Thampi	Nov/84	837.2413
84-323-P	Combustibility Evaluation of Byron Creek Coals in the CRF	M. Alvarez-Cuenca, R. Thampi, R. Mangal	Oct/84	830.16
C84-8-K	Quality of Ion Exchange Resins Thunder Bay TGS	J. Complak	Feb/84	836.3332 X836.352
C84-61-R	Combustibility Testing of Western Canadian Coal	M. Alvarez-Cuenca, R. Mangal	Aug/84	836.413
C84-93-K	Boiler Tube Deposits - Lakeview Unit 2	P. McSweeney	Sept/84	836.333

ENVIRONMENTAL

Report No	Title	Author(s)	Date Issued	File
84-25-K	Booth Quarry Groundwater Monitoring, November '83	A. Golomb	Mar/84	837.71
84-60-H	Reverse Osmosis of Treatment of Fly Ash	A. Golomb	Apr/84	837.332
84-64-H	Electrodialytic Regenerant Recovery	B.R. Nott	Apr/84	837.33
84-67-K	Post Operational Ash Cell Groundwater Monitoring Program - 1982 - Thunder Bay TGS Extension	J. Complak	Feb/84	837.71
84-103-K	Post-Operational Fuel Storage Area Ground Water Quality Studies 1983 - Thunder Bay TGS Extension	J. Complak	July/.84	837.331
84-108-K	Post-Operational Ash Cell Ground Water Quality Studies 1983 - Thunder Bay TGS Extension	J. Complak	July/84	837.71
84-176-H	Preliminary Economic Assessment of Recovery of Coal from the Cumberland Mine Rejects	Y. Nguyen	June/84	837.242
84-219-K	Aqueous Organic Emissions (PAHs) Survey	A. Golomb	Nov/84	837.71
84-389-K	Booth Quarry Ground Water Monitoring - June 1984	A. Golomb	Jan/85	837.71

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84-452-K	Domtar Quarry Ground Water Survey - Third Annual Report 83-84	A. Golomb	Dec/84	837.71
84-453-K	Domtar Quarry Surface Water Survey - Third Annual Report 83-84	A. Golomb	Dec/84	837.71
C84-4-K	PO_4 Removal from Pickering GS 'B' Pipe Cleaning Waste	B.R. Nott	Jan/84	837.39
C84-28-K	Atikokan TGS - Ash Disposal Preoperational Groundwater Survey - 1st Annual Report 1982 - 1983	A. Golomb	Mar/84	837.71
C84-37-K	MOE Coal Ash Extraction Tests - Progress Report March 1984	A. Golomb	Mar/84	837.71
C84-38-K	Alkalies in Thunder Bay Lignite	S. Chilakos	Mar/84	837.242
C84-42-K	Atikokan TGS - Ash Disposal Pre-Operational Ground Water Survey - 2nd Annual Report, 1983-1984	A. Golomb	July/84	837.71

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